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Addressing the mechanical deformation of flexible stamps for nanoimprint lithography on double-curved surfaces

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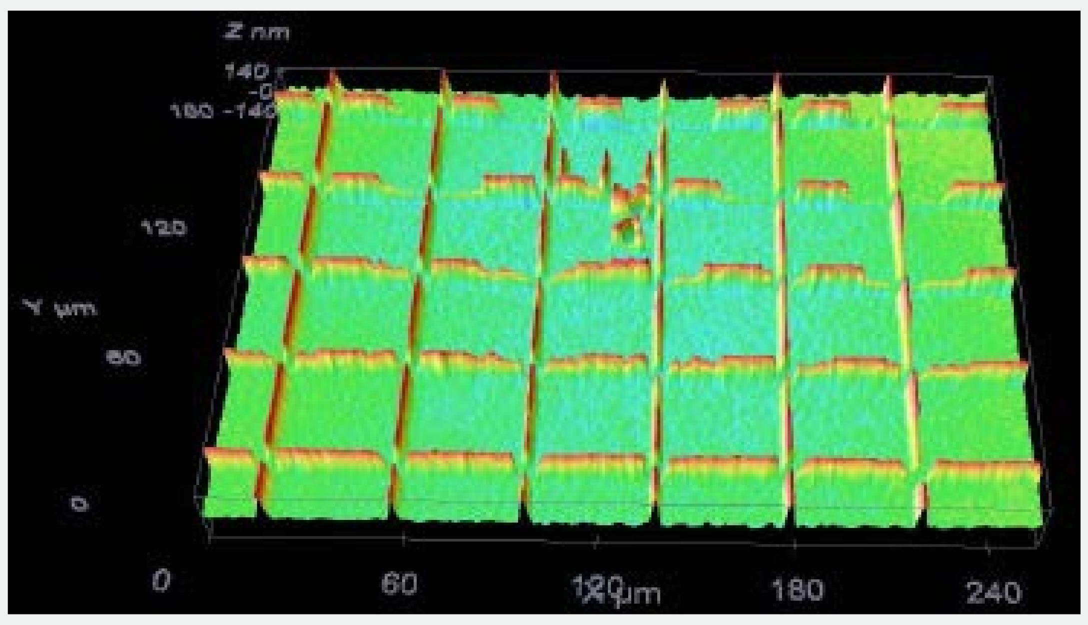
Resolution limits due to distortion, and complications regarding deformations of the flexible stamps, has been addressed as a major concern by serveral authors dealing with nanoimprint on not planar surfaces. Here, a mechanical engineering approach for tracking mechanical deformations of flexible stamps for nanoimprint lithography on double-curved surfaces is presented. The basic idea is that by tracking the deformation of a square grid pattern on the stamp, it is possible to calculate the principal strains.



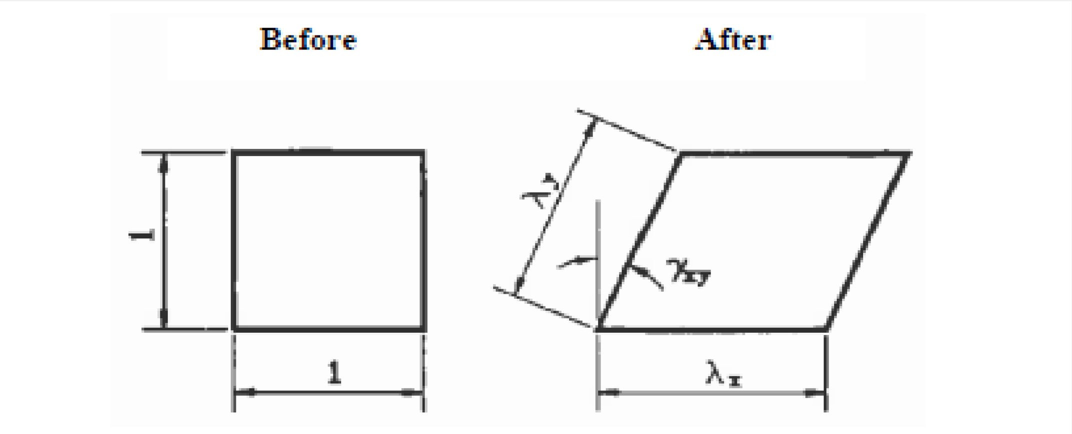
Square grid on planar flexible stamp before deformation

Herold's method [1] is for this task very suitable, where the stretch ratio for a square is given by

$$\lambda_{1,}^2\lambda_2^2 = \frac{\lambda_x^2+\lambda_y^2}{2} \pm \sqrt{\left(\frac{\lambda_x^2+\lambda_y^2}{2}\right)^2 + \lambda_x^2\lambda_y^2 sin^2\gamma_{xy}}$$

, and the principal strain then can be found by

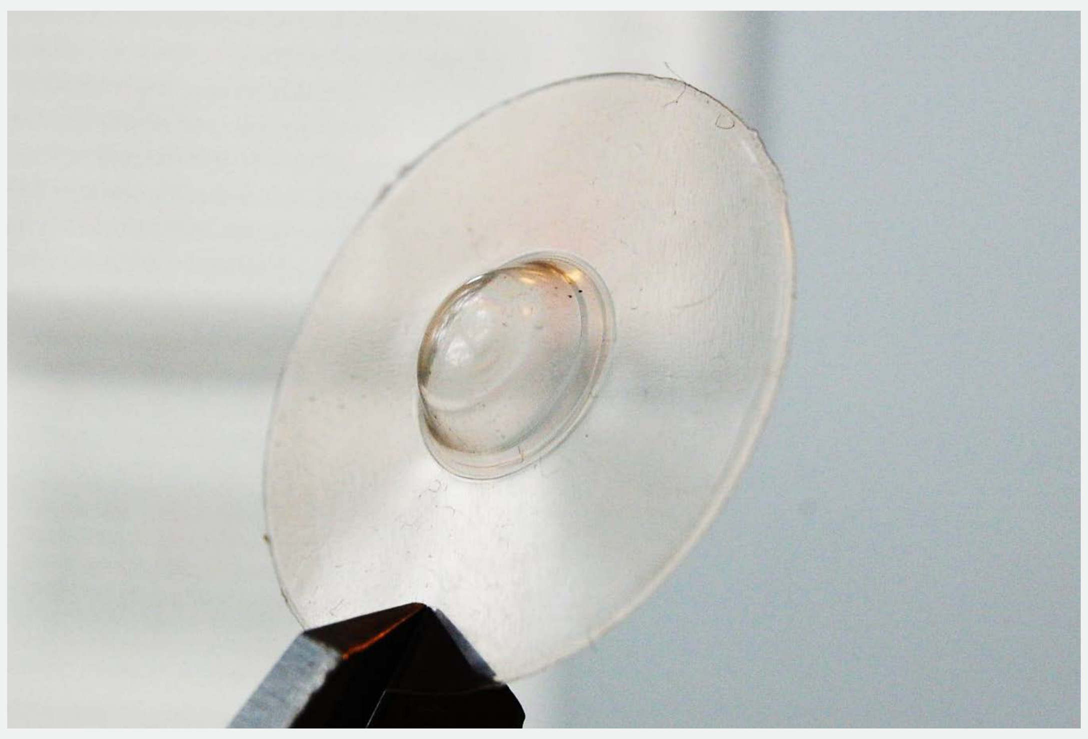
$$\varepsilon_a = ln(\lambda_a)$$



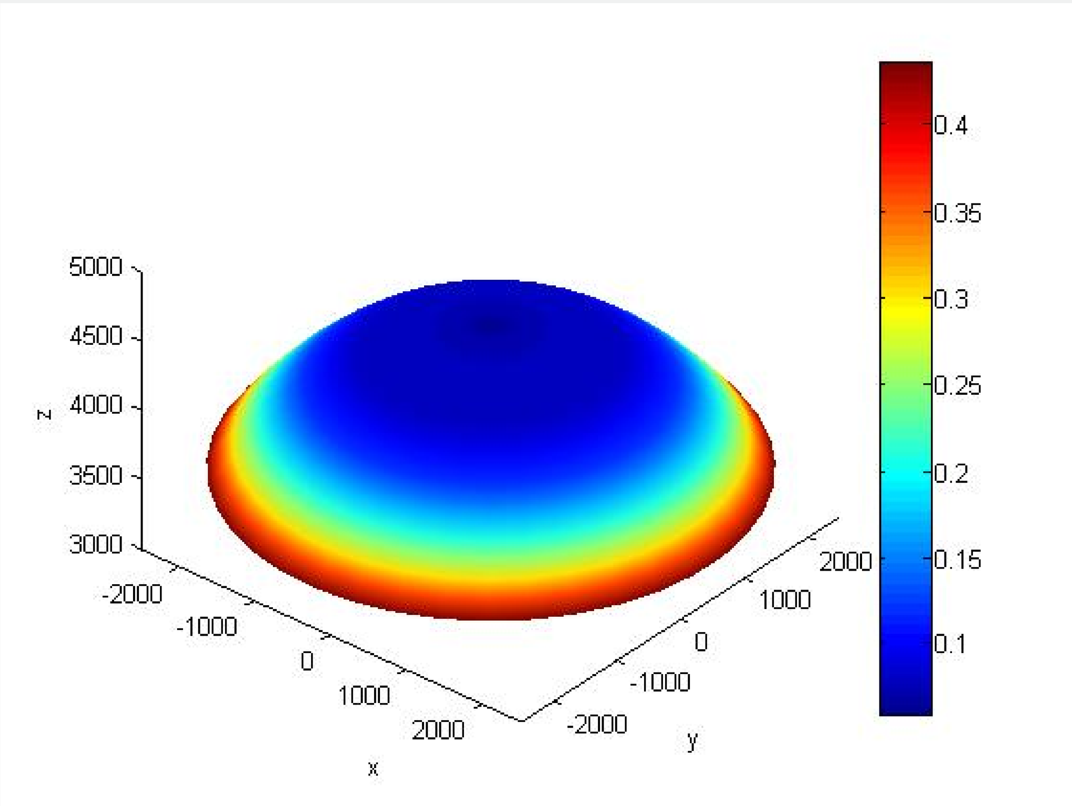
Deformation of a square into a parallelogram in a homogeneous strain field

To make high resolution nanoimprints on curved surfaces, the mechanical deformation of the flexible stamp must be taken into account –you cannot wrap an orange without folding or stretching the wrap material.

An experiment was performed, which shows the capabilities of the developed algorithm for determining principal strains in the mechanically deformed flexible stamp. A stamp was made of 190 µm thick PTFE folio. From a silicon master stamp, the square grid pattern was transferred to the PTFE sheet by embossing. The pattern consisted in this case of 2 µm wide grid stripes with a center to center separation of 40 µm distance. The flexible stamp was deformed in a biaxial (double-curved) stretching by a steel sphere with a radius of 4.5 mm mounted in an uniaxial tensile test machine. After deformation, the surface of the flexible stamp was characterized using a Sensofar Plu neox 3D Optical Profiler. For the confocal measurements an EPI 50X/NA 0.80 objective was used. Data files of the topology were then put into the developed deformation code in MATLAB , and it was then possible to plot the principal strains on the deformed flexible stamp.



Deformed PTFE flexible stamp



Maximum principal strains plotted on top of the deformed flexible stamp

Critical principal strains were found down the edge of the deformed stamp, with values of ε_1 = 0.42 and ε_2 = 0.06. One square in the grid close to the edge would after deformation have dimensions of 42.47x60.88 µm. This is a huge difference in size compared to the initial planar geometry (40x40 µm). For example if the color from a diffraction grating desired is green, with a wavelength of approximately 510 nm, this would in the deformed case have increased to 776.2 nm and would therefore not be functioning.

Fabrication of the master silicon stamp and the flexible stamp was performed by NIL Technology ApS, a partner in the NANOPLAST project. This work is financially supported by The Danish National Advanced Technology Foundation, which is highly acknowledged.

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